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Affective Sensing + Wearable Imaging: Vision Impairment and implications for Spatial Enquiry

Marissa Lindquist, Queensland University of Technology, m.lindquist@qut.edu.au
& University of Newcastle, Marissa.Lindquist@uon.edu.au
Anthony Williams, University of Newcastle, tony.williams@newcastle.edu.au

Abstract

Recent interest in affect and the body have mobilized a contemporary review of aesthetics and phenomenology within architecture to unpack how environments affect spatial experience. Emerging spatial studies within the neuro-sciences, and their implications for architectural research as raised by architectural theorists Juhani Pallasmaa (2014) and Harry Mallgrave (2013) has been well supported by a raft of scientists and institutions including the prestigious Salk Institute.

Although there has been some headway in spatial studies of the vision impaired (Cattaneo et al, 2011) to understand the role of their non-visual systems in assisting navigation and location, little is discussed in terms of their other abilities in sensing particular qualities of space which impinge upon emotion. This paper reviews a collection of studies exploring face vision and echo-location, amongst others, which provide insight into what might be termed *affective perception* of the vision impaired, and how further interplay between this research and the architectural field can contribute new knowledge regarding space and affect.

By engaging with themes from the Aesthetics, Phenomenology and indeed Neuro-science fields, the paper provides background of current and potential cross disciplinary research, and highlights the role wearable technologies can play in enhancing knowledge of affective spatial experience.

Vision Impairment; Spatial Environments; Spatial Perception;
Affective Spatial Perception; Congenitally Blind, Wearable Imaging

In November 2004, Alan Saunders host of the Australian Broadcasting Corporation (ABC) Radio National Program '*The Comfort Zone'* interviewed writer and teacher Rebecca Maxwell, and architect Peter-John Cantrill, (Zanis Associates). Entitled '*Beyond Appearances: Architecture and the Senses*', the interview focused upon non-visual spatial experience, Rebecca had lost her sight early in her childhood. Whilst discussing her way-finding experiences, Rebecca described her sensory perception of particular formations of space, and revealed that when experiencing low ceiling heights felt:

> '...an oppression that I work out by checking with someone else that it is connected with a low ceiling, or a disproportion of the space...there are proportions that are comfortable and proportions that aren't, and the ceiling height is an important part'. (Saunders, 2004)

Further, she expressed that:

> '...an air-conditioned building feels dead. It becomes amorphous, too homogenous and that even the size of space is lost' and called on architects to try'and feed the senses when designing' (Saunders, 2004).

Rebecca's comments reflect numerous studies (Cattaneo et al., 2011; Andreou et al., 2010; Passini et al., 1990; Roder et al., 1999) concerning the enhanced capacity of the visually impaired in sensing internal and external qualities of space. In key studies of the blind (Cattaneo et al., 2008; Mitchell, 2007; Roder et al., 1999), early blind participants are observed to perform as well as sighted in regards to space due to higher auditory and somatosensory (skin sensations) spatial acuity. This capacity is understood as an artefact of cross-model plasticity induced by deficiencies in the visual cortex (Kupers et al., 2011; Mitchell in Plumert et al., 2007). These observations raise questions as to how the vision impaired comprehend space, and indeed, how sensitive they are to psycho-affective (pleasant/unpleasant) conditions informed by architectural environments. Further, how can findings from spatial studies involving the blind, inform new spatial and affective considerations within architectural design?

This paper reviews a collection of studies exploring face vision, and echo-location amongst others which provide insight into what might be termed *affective perception* of the vision impaired, and how further interplay between this research and the architectural and design fields can contribute new knowledge in regards to space and form, and its impact upon emotion and experience. By engaging with themes from the aesthetic, phenomenology and indeed neuro-science fields, the paper will provide background of current and potential cross disciplinary research, and further highlight the role new wearable technologies can play in enhancing knowledge of the affective impact of spatial experience, as currently explored at the PASlab (QUT), Australia.

Spatial Aesthetics + Architecture

In '*Architecture and Aesthetics',* Macarthur & Stead (2012) note that although notions of pleasure, corporeality and affect might be discussed within architectural theory, there is 'little serious attention given … to the older questions of whether it aims to please the senses and if so, how' (2012, p.123). The authors point to the impact Heinrick Wolfflin (1965) and Rudolf Arnheim's (1977) psychology studies had upon the techniques of architecture - scale, movement, and texture, as concrete examples of how aspects of architecture have a direct description in human psychology.

In describing the context of phenomenology, Macarthur & Stead (2012) argue its value in that it is 'the dominant mode in architecture where the question of sense and affects is posed'… 'and is used as a lens to propose directly how the spaces we inhabit make us feel' (2012, p.127). They suggest that:

> 'The idea that architecture can be made better through understanding our perception of space and putative spatial archetypes begins in the eighteenth century, takes its modern form in the late-nineteenth century in empathy theory, grows in empirical psychology in the mid twentieth-century, and is reviving today in an uptake of neuropsychology' (2012 , p. 128)

This position is taken up in the recent publication *Architecture and Embodiment: The Implications of the New Sciences and Humanities for Design* (Mallgrave, 2013). Mallgrave fits phenomenologists Heidegger and Maurice Merleau-Ponty's theories alongside Gibson's ecological views of perception ('affordances' and 'environmental field'), which suggest a complementary and reciprocal connectedness between organism and their environment. Key questions posed in regard to architecture and indeed design experience are, on what levels does spatial experience unfold? And further, what is its relation to rapidly changing cultural [and technological] conditions?' (2013).

Mallgrave points to Robert Vischer's (1873) early work on feelings (Fuhlung) and empathy (Einfuhlung) as key to notions of embodiment in aesthetics and architectural experience. Empathy is seen as a projecting of self into other (bodies and space) in order to understand relations and gain deeper understanding of experience. Recent neurological studies into emotional formation and context also underline the impact of architectural space upon experience, such as Biederman and Vessel (2006) fMRI studies, which explored favourable or unfavourable responses to image environments, both in architectural and natural settings. Mallgrave also notes Bud Craig's (2009) investigations of feelings in relation to context, suggesting that built environments 'might also play out on the sympathetic or parasympathetic circuitry…. those that encourage parasympathetic activity and lead to somatic and visceral relaxation, and those negative feelings that initiate sympathetic activity and energy expenditure'(2013, p.112).

Researchers involved in Aesthetics (Nadal and Skov, 2013), point toward an interdisciplinary approach which re-values the theoretical underpinnings of aesthetics for broader application such as in the fields of spatial design and architecture. Nadal and Skov (2013) note that traditional fields such as neuroscience, psychology and evolutionary theory engage with neuro-aesthetics, but from different perspectives and that recent research in the different experimental techniques, design, and quantitative methods for measuring aesthetic experience could strengthen the relations between scientific fields. Further, they note the preponderance of neuro-imaging research as a popular approach to investigate aesthetic judgements of stimuli and their associated neural processes (2013).

These views provide background for phenomenological enquiry within architecture, and demonstrates a shift in architectural aesthetics toward research underpinned by advancements in neuropsychology and neuroscience (McCarthur and Stead, 2013; Mallgrave, 2013). Evidence of this is seen through the gamut of studies into bodily experience and spatial affect currently undertaken through architectural research, which turns away from approaches based on stylistic or abstract tendencies. The literature also recognises architecture as the site for experimentation into space and affect, in particular investigations which engage with continuous real time interactive experiences of architectural space and environments to replace a legacy of static spatial enquiry.

Vision Impairment + Spatial Studies

Research regarding the vision impaired has historically been considered through three theories of spatial perception as noted by Kitchen et al., (1997) and Cattaneo et al., (2011). *Deficiency Theory* (Golledge 1993), suggests that congenitally blind individuals (blind from birth) are unable to develop general spatial ability due to their visual deficiency. *Inefficiency Theory* (Spencer et al., 1989) suggests that people with visual impairments do have auditory and haptic dependent spatial ability, but is inferior to that enabled through vision. Finally, '*Difference Theory* (Passini and Proulx 1988) suggests that visually impaired individuals possess the same abilities to process and understand spatial concepts, and that any differences, either quantitatively or qualitatively, can be explained by variables such as access to information, experience or stress' (Kitchen et al, 1997 p. 229). The following literature presents review of qualitative (interview) and quantitative (neurological) studies investigating spatial and sensory perception from a *difference* perspective. The underlying theme drawn from these studies, suggests that the blind (both visually impaired and congenitally blind) demonstrate a greater propensity for *affective spatial perception* when compared to the sighted and makes the case for a new approaches to architectural and spatial research.

Studying the visually impaired is complex. Specific research themes must account for this variability in research study design. Cattaneo and Vecchi's recent and extensive publication '*Blind Vision: the Neuroscience of Visual Impairment*' (2011) note that:

> '…the cognitive abilities exhibited by blind individuals depend on an interrelation between subjective and experimental characteristics, such as the specific ability being tested, the specific task used and the experimental context.
>
> ...on the one hand 'the blind' cannot be regarded as a homogeneous population, but must be considered according to individual variables such as age, onset-age of their visual deficit, duration and etiology of that deficit, mobility capacities, braille-reading capacities and use of external devices...On the other hand, the nature of the designated task and task-related strategies are also extremely critical in affecting the behavioural output.' (Cattaneo & Vecchi, 2011, p. 115)

There is scant research as to how the visually blind learn and respond to geographical or spatial environments other than from traditional way finding studies (though research is developing through neurological enquiry). Architectural and spatial research engaging the blind and their affective appraisal of space is difficult to find. Studies of the vision impaired also tend to present bias depending upon the various frames of reference used to assess environmental perception. Kitchen et al., (1997) outline dominant frames of reference currently employed, such as: *egocentric frameworks*, knowledge which is tied to oneself; *fixed frameworks*, knowledge tied to features within the environment; and *global frameworks*, knowledge inferred from unknown environments regardless of direction. The latter two refer to *allocentric framework*s which rely on topographical relations for spatial enquiry. Frameworks are often paired with different forms of spatial processing specific to way finding; for example egocentric frameworks are often viewed as guided by sequential *processing* (route based), whilst allocentric frameworks are guided by *survey processing* (Euclidean based) (Passini et al., 1990). Kitchen et al., (1997) note the predominance of *egocentric route-type* frame of reference systems defining studies of the visually impaired and calls for research that engages with alternative frameworks to study their ability in assessing geometric characteristics of settings from a survey or allocentric position (See Passini & Proulx, 1988, in Kitchen et al, 1997).

Pow's (2000) study of social-spatial experiences of the visually impaired in the navigation of urban environments, proposes three (3) key non-visual strategies in sensing space. '*Auditory geographies'* concerning the blind, are said to engage with noise as both navigational and topological devise. '*Haptic geographies'* are said to engage with indirect tactile sensation and kinaesthesia in determining landmarks, textures and places within particular contexts. Finally, '*olfactory geographies'* are said to engage with odour signatures associated with a particular place and time (referencing Porteus, 1985). This perspective echoes recent *qualitative* studies which focus on the detection of *'action centred near environments',* and to some degree their *affective appraisal*, reported by the visually impaired.

Kells (2001) undertook a phenomenological interview of the vision impaired regarding their experience of *face vision. Face Vision* is described as a feeling of pressure on the exposed area of the skin which provides information as to objects within near environments. The study reported that participants knew the shape, planning and density of a relatively unfamiliar space. Further, participants who were asked to describe their perception walking within an environment, sensed or 'felt' the space as closed, open or distorted, adding:

> '"I kind of know what rooms are shaped like and how things are laid out...I can … pretty much [tell] what kind of furniture it is by how dense it is."
>
> 'Another participant said an indication of a corner or doorway is that "you'll feel an openness [in the space] where…there's no walls"' (Kells, 2001, p.155).

Similarly, Andreou & McCall (2008) interviewed twelve (12) visually impaired children to record their explanation of obstacle awareness in space. They note phenomenon such as *sound shadows*; where an object is between the sound and the individual; *sound reflectance or echo-location*; the recognition of objects on the basis of reflected sound (Ashmead et al., 1989) as well as *face vision* (Lopes, 2000) as factors in object detection within space. The researchers found that children which used these faculties expressed a 'sense' or 'feeling' of objects within their environment, and that in many instances had an instantaneous impression of the layout of a new room, whilst also sensing auditory cues without being overtly aware (2008). Of note, was one participant's observation which noted that:

> '"…I can usually sense if I am like near a wall or something. I can usually tell if it's a low down ceiling or something…I can tell…where things are…for example in here I can sense where the pool table is in relation to the chairs"' (Andreou & McCall, 2008, p. 121)

In an additional study, Andreou and McCall (2010) interviewed a congenitally blind child regarding spatial perception over a six month period. The study reported on the child's strategies to comprehend space. These included *reference to external items and egocentric frameworks* to assess dimensions of rooms, ceiling heights, objects and doorways; and *reference to auditory environments* to detect various ceiling heights. The child also reported on more complex spatial acuity such as *forming mental images of defined space* by synthesising auditory and kinaesthetic information into a spatial mapping process; and *deductive reasoning* to compare variation in form and affect between ceiling qualities (domestic space vs. cathedral space) (Andreou & McCall, 2010). Of note was the child's response regarding small rooms, expressing that there was a 'dull sense, with minimal echo' (Andreou & McCall, 2010, p.121), which concurs with Maxwell's (2004) emotional and physical responses to space as noted at the beginning of this paper.

These qualitative studies point to the abilities of the blind to provide insight into the methods we all use in structuring spatial experience. They also reveal how architectural or interior

space can impact upon experience at a bodily level informing deep emotional response, which may in turn affect our psychological disposition.

Wearable Technologies + Spatial Experience

Neurological studies assessing perceptual functions of the visually impaired have emerged over the past twenty (20) years (for extensive reviews see Cattaneo & Vecchi, 2011). Though mostly limited to fMRI, more contemporary studies are investigating new wearable neuro-imaging devices to engage with perception and way-finding. Investigation into the nature of consciousness of the visually deprived brain highlights compensational tendencies resulting in cross-modal plasticity. Kupers et al., (2011) note that topographical representations (external perceived objects/forms) within the visual cortex does not require visual experience. Object and form recognition through tactile or somatosensory inspection is shown to represent same neural patterning as visual inspection, particularly manmade objects. They note that spatial information and motion discrimination is processed in a supramodal fashion; that is, recruiting from other areas of cortex depending on impairment, suggesting that actual visual experience is not a dominant factor (2011).

Significantly, Mitchell (2007) reviewed a number of neuro-cognitive studies assessing whether spatial representations can be developed in the absence of visual or auditory input sufficient to support *accurate* spatial perception and cognition. In other words, can the blind describe 'near' architectural environments, and can this be traced neurologically? Studies employed auditory localisation (whilst in motion) and reach experiments revealing more accurate outcomes for congenitally blind (Ashmead et al., 1998). Ashmead et al., (1998) in their paper *Echolocation reconsidered: using spatial variations in the ambient sound field to guide locomotion*' assessed the auditory perception of 13 blind children (whilst blindfolded) in sensing ambient sounds within three hall way conditions that varied in width (narrow - 1.5m, medium - 2m and wide - 3m), whilst hearing was occluded or unoccluded. The study showed that spatial tuning was sharper for the blind in the periphery, and that medium widths are best attuned. In terms of locomotion, the paper noted that through enhanced attention, the congenitally blind can perceive naturally occurring gradients of ambient sound whilst moving (Mitchell, 2007) and that 'self-motion is critical in the traveller's ears through variations perceived in the ambient sound field' (Ashmead, 1998, p.621).

Wearable imaging devices such as electroencephalography (EEG) are supplementing more traditional investigations into aesthetic or spatial experience, though studies are limited with regard to the vision impaired. The research represents the emergence of neuro-imaging used to investigate affective responses of everyday experience due to innovations in statistical analysis. Recently, Gramann et al.(2010) used a mobile brain/body imaging (MoBI) application integrating EEG and motion capture to successfully record brain and body dynamics with sighted participants. The authors noted the inherent restrictions of fixed brain

imaging such as fMRI, where virtual reality systems 'can be used, [however] participants in such experiments neither produce natural behaviour nor experience the concomitant proprioceptive and vestibular sensations' (Gramann et al., 2010, p.1 [my emphasis]).

The People and Systems Lab [PASlab, QUT] Australia, are currently trialling new neuro-imaging devices such as Near Infrared Spectroscopy (NIRS), to understand its efficacy in architectural or spatial research. NIRS is an optical method to measure blood (hB) oxygenation levels within human tissue for a range of physiological, neurological and clinical enquiries, including emotion studies (Hoshi et al., 2002/2011; Plichta et al., 2011; Asano et al., (2013). Lloyd-Fox (2010) and others note that neuronal activation originates in the neurons as electrical signals which are transmitted between cells. This activation provokes an increase in oxygen consumption, local cerebral blood (hB) flow and oxygen delivery (Lloyd-Fox et al., 2010). Cognitive or affective experiences activate tissue and blood dynamics within cortical areas critical in the functioning of required perceptual and physiological responses to each experience context. The PASlab researchers have adapted previous vision impaired spatial studies by including the NIRS wearable imaging device in the hope to quantify in real time, the affective perception of the vision impaired to spatial qualities from an architectural/interior perspective.

Wearable Technologies + Spatial Experience

Research reviewed here suggest that somatosensory (*face vision* etc) and auditory processing within the cortex, enables the vision impaired to sense and detect spatial environments. Rather than solely employing ego-centric, sequential or route based reference systems, in some reported instances the vision impaired recruit other sensory modalities to perceive architectural and urban spaces in allocentric (survey) fashion. Qualitative studies point to the ability of the vision impaired (particularly congenitally blind) to describe qualities of interior space, not just in navigation but in terms of spatial affect, through deductive reasoning and spatial imagery. As noted, research findings suggest that the vision impaired experience conscious feelings of 'oppression' or 'weightedness' associated with low ceiling heights or disproportionate space (Andreou & McCall, 2008; Saunders et al., 2004; Kells, 2001) revealing a deeper perceptual sensitivity then would be expected. This *affective spatial perception* is significant, as it suggests possible underlying conditions within architectural and spatial environments that might impinge upon wellbeing at a neurological level in both sighted and impaired**.**

The underlying theme drawn from this literature, as Proulx (2014) suggests is that the vision impaired are experts in using their other faculties in assessing spatial environments. By engaging with opportunities afforded by real time, non-invasive imaging to understand how the vision impaired appraise or respond to space, there is the potential to reveal at a neurological level the impact of space upon their wellbeing. By understanding the *affective perception* of the vision impaired and the further interplay between this research,

architecture and wearable imaging, new knowledge in regards space and its impact upon emotion and experience can be found.

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Author Biographies

Marissa Lindquist

Marissa Lindquist is an award winning architect with over 10 years practice experience and lecturer at the School of Design, Queensland University of Technology. In 2008 she was awarded the Dulux Study Tour for emerging architects in Australia. She formed part of the editorial team for the international IDEA Symposium [2010] entitled Interior Spaces in Other Places, Brisbane, Australia, and is recognised for her creative practice through publication within the 2012 Venice Biennale Australian Pavilion Catalogue. Marissa is currently undertaking her Phd focusing upon neuro-imaging, architecture and emotion, with specific interest in the visually impaired. Her teaching practice dwells on the margins of interiority, perception and craft making. She sits on the Executive for the Design and Emotion Society, Australian Chapter.

Anthony Williams

Professor Anthony Williams is Vice-President – Academic and Research, Avondale College, and holds a conjoint position at University of Newcastle University of Newcastle, Australia. He is a winner of multiple University Teaching Awards, as well as a National Award for

Teaching Excellence. Tony has worked extensively in curriculum design and implementation, both at program and course levels, and has worked as a curriculum consultant both nationally and internationally. He is widely published in the field of Design and Engineering Education, with over 100 publications in these particular professional fields.